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Is it possible to improve science process skills and attitudes towards chemistry through the development of metacognitive skills embedded within a motivated chemistry lab?: a self-regulated learning approach

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Abstract

The aim of this study was to improve pre-service science teachers' science process skills and attitude towards chemistry by developing their metacognitive skills embedded within a motivating chemistry laboratory. The sample of the study was 54 pre-service science teachers who took the first year chemistry lab course at Marmara University. Both the control (n=27) and the experimental group (n=27) carried out 11 experiments, each of which was performed over a lab course. The students comprising the control group performed the experiments following the instructions described in the laboratory manual. However, in experimental group pre- and post-discussions about the design of the experiments were held in order to create metacognitive awareness of the experimental design. The students in the experimental group were always encouraged during the course and were given four semi-structured reflective interview forms developed by the authors. Differently from the control group, the students in the experimental group were asked to inquire the subjects the researcher wanted them to do so. While the students in the control group had no feedback for their reports, the students in the experimental group had always positive feedbacks. The results showed that the experimental group outperformed the control group in the Science Process Skill Test, particularly in the categories of identifying variables, operationally defining and designing investigations. The first and the last interview forms, which were given at the beginning and the end of the semester, were used for a deeper analysis of the students' metacognitive skills, motivation and attitude towards the course. The second and the third reflective forms were used to create metacognitive awareness in students. Although the students reflected very positive feedbacks for the last interview form, results of the t-test analysis showed that no significant gain could be achieved either in control or experimental group in terms of their attitudes towards chemistry.

Keywords: metacognitive development; science process skills; motivation; attitude towards chemistry.

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1. Introduction

Laboratory instruction has long had a significant role in science education and literature pointed out the gains of students from engaging science laboratory activities (Tobin, 1990; Garnett, Garnett & Hacking, 1995; Hodson, 1996; Hofstein & Lunetta, 1982; 2004; Freedman, 1997). Despite the benefits of laboratory work, the students rarely focus on their purposes. In other words, student try to see or determine only the expected results from the activities, but they do not invest much mental engagement in relating other learning experiences to laboratory work (Hart, Mulhall, Berry & Gunstone, 2000). Laboratory instruction should give students wider range of learning experiences than verifying textbook claims (Tsai, 2003).

In recent years, the main focus in science classrooms has been on mastering science skills and doing science as it is practiced in real laboratory situations by working scientists (Shuh, 2002). In contrast to traditional science instruction, which emphasize lectures to efficiently present scientific information and encourage students to memorize facts from textbooks, today's scientific instruction emphasize on problem-solving, inquiry-based laboratory activities and rejection of science as a body of facts that must be memorized (Stuart & Henry, 2002). Although the development of lab skills may be a useful component of scientific learning, it is not sufficient to develop student science process skills. Students may follow the lab procedures, following the step-by-step process outlined in a manual without really understanding the scientific process. In order to make the laboratory activities more effective, other aspects of science process skills, such as identifying problems, developing experimental designs and applying quantitative measures need to be developed by students (Shimizu, 1997).

A considerable number of literature has stressed science teachers' low attitude towards science and their low confidence and self-efficacy beliefs in teaching science (Talsma, 1996; Mulholland & Wallace, 1999; Appleton, 2002; Garcia, 2004; Taylor & Corrigan, 2005). Literature also shows that negative feelings towards science affect teaching self-efficacy negatively (Tarık, 2000). If teachers feel that they can teach science effectively and have the skills they need to perform experiments effectively, then it appears that good science instruction will be simply a matter of giving classroom teachers ideas and strategies that they can use to teach science using inquiry process. University-level teacher training programs need to reflect more of what the teachers will need in the classroom and process skills need to be emphasized more in the classroom. The lessons should also involve inquiry learning and promote social interaction (Garcia, 2004).

Motivation and interest are also significant components for effective learning in science (Taylor & Corrigan, 2005). It is the student who decides to engage in learning or not (Pintrich, 2000). Fishbein's expectancy-value theory suggests that an individual's attitude toward any object is a function of his beliefs about the object as well as the implicit evaluative responses associated with those beliefs. In Fishbein's model, beliefs affect attitudes and these attitudes then affect intentions and behaviors (Weinburgh & Englehard, 1994). Weinburgh & Englehard's study examined the students' attitude towards biology laboratory experiences and found that students, who have positive beliefs about the usefulness of laboratory experiences, tend to report positive attitude toward working in the laboratory. This result supported Fishbein's expectancy-value model. However, Weinburgh and Englehard suggest that additional research that focuses on student attitudes toward science in general and also within specific disciplines is needed (1994).

In self-regulated learning perspective, metacognition should also be taken into consideration. In recent years, metacognition is regarded as an important factor of learning in science. In many research studies of science teaching it was found that metacognitive processes promote meaningful learning, or learning with understanding (e.g., Baird, 1986; Gourgey, 1998; White & Mitchell, 1994; Rickey & Stacey, 2000; Thomas & McRobbie, 2001; Davidowitz & Rollnick, 2003). Most of these researchers suggest that one of the main characteristics of meaningful learning is the student's ability to *control* a problem-solving process and the performances of other learning assignments. These researchers link this *control* to the student's *awareness* of his/her physical actions during the performance of a certain task (Kipnis & Hofstein, 2008).

In 21st century, a continuously changing world, not only is it impossible for individuals to acquire all existing knowledge but it is also difficult to foresee which knowledge will be essential for the future (Georghiades, 2004). The development of metacognitive abilities that will enable the student to study any desirable knowledge in the future becomes essential (Kipnis & Hofstein, 2008). Attaining essential information requires the learner to be aware and control of his/her knowledge and of the options to expand it. This means that the student must utilize and develop metacognitive skills (Kipnis & Hofstein, 2008).

1.1. Self-regulated learning

Self-regulated learning is an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate and control their cognition, motivation and behavior, guided and constrained by their goals and the contextual features in the environment. Self-regulated learners are viewed as active, constructive participants in the learning process. Learners are generally assumed that they can potentially monitor, control and regulate certain aspects of their own cognition, motivation and behavior as well as some features of their environments (Pintrich, 2000). According to Zimmerman's definition (1986), students are self-regulated to the degree that they are metacognitively, motivationally and behaviorally active participants in their own learning process. Of the three subprocesses of self-regulation, the components of metacognition and motivation are the concern of this study.

1.1.1. Metacognition

Metacognition includes skills that enable learners to understand and monitor their cognitive processes (Schraw, Crippen & Hartley, 2006). According to Schraw's model (1998), there are two main subcomponents in the matecognition:

1. *Knowledge of cognition* refers to what individuals know about their own cognition or about cognition in general. It includes three different kinds of metacognitive awareness: declarative, procedural and conditional knowledge.
    - *Declarative knowledge* includes knowledge about oneself as a learner and about factors that influence one's performance (knowing 'about' things).
    - *Procedural knowledge* refers to knowledge about doing things. Much of this knowledge is represented as heuristics and strategies (knowing 'how' to do things).
    - *Conditional knowledge* refers to knowing when and why to use declarative and procedural knowledge (knowing the 'why' and 'when' aspects of cognition).
2. *Regulation of cognition* refers to a set of activities that help students control their learning. Although a number of regulatory skills have been described in the literature, three essential skills are included in all accounts: planning, monitoring and evaluation.
    - *Planning* involves the selection of appropriate strategies and the allocation of resources that affect performance. Planning includes goal setting, activating relevant background knowledge and budgeting time.
    - *Monitoring* includes the self-testing skills necessary to control learning. It refers one's on-line awareness of comprehension and task performance.
    - *Evaluation* refers to appraising the products and efficiency of one's learning. Re-evaluating one's goals, revising predictions and consolidating intellectual gains.

Regarding the laboratory activity, knowledge of cognition should be reflected during the discussion about the observations by asking appropriate questions and operating a suitable inquiry stage. Regulation of cognition should be expressed during the planning of the experiment, while performing it and evaluating the results regarding the assumption (Kipnis & Hofstein, 2008).

1.1.2. Motivation

Although there are many motivational theories that include some type of expectancy and value constructs, this study focused on one model that has generated the most theory and research on academic achievement in classroom settings. The model comes from the work of Eccles and Wigfield and their colleagues (e.g., Eccles, 1983; Eccles, at al., 1989; Wigfield, 1994; Wigfield & Eccles, 1992, 2000). This social cognitive model focuses on the role of students' expectancies for academic success and their perceived value for academic tasks and arose from a general organismic perspective based in personality, social and developmental psychology (Pintrich & Schunk, 2002).

In this social cognitive expectancy-value model achievement behavior is predicted by two general components: expectancy and value. The value construct refers to a student's response to a question, "Why should I do this task?"

(Eccles, 1983). Responses would include interest (I'm interested in this topic), importance or utility beliefs (This topic is important or useful to me for my future career) and costs (If I take this difficult course, I will not be able to play sports) (Pintrich & Schunk, 2002).

In contrast, the expectancy constructs refers to the question "Am I able to do this task?" (Eccles, 1983; Wigfield, 1994; Wigfield & Eccles, 1992). Expectancy refers to actual beliefs of students about their future expectancy for success; that is, whether they believe that they will do well on a task (Pintrich & Schunk, 2002).

In Bandura's (1977) theory, motivation is activated and maintained by expectations concerning the anticipated outcomes of actions and self-efficacy for performing those actions. Bandura (1977) defines an outcome expectancy as a person's estimate that a given behavior will lead to certain outcomes and an efficacy expectation as the conviction that one can successfully execute the behavior required to produce the outcomes. From a motivational perspective, outcome expectations are important because students think about potential outcomes of various actions and act in ways they believe will attain the outcomes they value. Academically motivated students believe if they study diligently, they will make good grades (Pintrich & Schunk, 2002). Outcome and efficacy expectations are differentiated because individuals can come to believe that a particular course of action will produce certain outcomes, but question whether they can perform those actions (Bandura, 1977).

1.1.2.1. Self-efficacy

Self-efficacy is people's judgments of their capabilities to organize and execute courses of action required to attain types of performances (Bandura, 1986, p. 391). Self-efficacy affects choice of activities, effort and persistence. People holding low self-efficacy for accomplishing a task may avoid it; those who believe they are capable are likely to participate. Especially when they encounter difficulties, efficacious students work harder and persist longer than those with doubts. People acquire information to appraise self-efficacy from their actual performances, vicarious (observational) experiences, forms of persuasion and psychological symptoms (Pintrich & Schunk, 2002).

Although efficacy beliefs and outcome expectations are usually related, it is possible for a student to have relatively high self-efficacy for a task but a negative outcome expectation. However, an individual's behavior largely determines the actual outcome and in the same way, beliefs about outcome expectations are dependent on self-efficacy judgments. Teachers who are not confident about their capability to foster student learning may dwell on negative images about their classrooms; those with greater confidence are apt to think of their students as motivated to learn (Pintrich & Schunk, 2002).

Self-efficacy has been shown to be an important mediator of all types of achievement behavior as well as many other types of behavior. Self-efficacy is similar to task-specific self-concept and self-perceptions of competence because each represents individuals' judgments of their capabilities. At the same time, self-efficacy is more situation specific than are the other expectancy constructs. This assumption has led researchers to measure self-efficacy in a situationally sensitive fashion and at a microanalytic level. Related to this situational specificity, self-efficacy beliefs are assumed to be more dynamic, fluctuating and challengeable than the more static and stable self-concept and self-competence beliefs. One's self-efficacy for a specific task on a given day might fluctuate due to the individual's preparation, physical condition (sickness, fatigue) and affective mood, as well as external conditions such as the nature of the task (length, difficulty) and social milieu (general classroom conditions). In contrast, other views of self-competence view it more globally (e.g., math competence) and are less concerned with microlevel instability of beliefs (Pintrich & Schunk, 2002).

1.1.2.2. Goal orientation

There are a number of different models of goal orientation that have been suggested by different achievement motivation, but the main construct that is involved is goal orientation, which concerns the purposes for engaging in achievement behavior. In contrast to Locke and Latham's (1990) goal setting theory, which focuses on specific goals (e.g., wanting to get 8 out of 10 correct on a quiz or trying to get A on a midterm exam), goal orientation theory is concerned with why individuals want to get 8 out of 10 correct, why they want to get an A. The goal-content approach focuses on many different possible goals that can guide behavior, while goal orientation remains focused on the goals and purposes for achievement tasks (Pintrich & Schunk, 2002). Although there are several definitions of goal orientation in literature, it can be defined as the reasons why people engage in a task (Pintrich, 2000; Pintrich & Schunk, 2002).

Most models propose two general goal orientations that concern the purposes why individuals are pursuing when approaching and engaging in a task. Those two goal orientations are labeled as learning and performance goals (Dweck & Legget, 1988), or task-involved and ego-involved goals (Nicholls, 1984), or mastery and performance goals (Ames, 1992), or task-focused and ability-focused goals (Maehr & Midgley, 1991). We will use the terms mastery and performance goals to refer to the two general goal orientations.

A *mastery goal* orientation refers to focus on the development of knowledge, skill and competence according to self-set standards or self-improvement. In this manner, mastery goal orientation is self-referential. Researches showed that individuals who have mastery goals did not avoid learning and mastering the task but avoided misunderstanding. In contrast to a mastery goal, a *performance goal* orientation reflects a focus on demonstrating competence and ability by trying to outperform peers on academic tasks. Performance goals concern how ability will be judged relative to others, using normative and social comparative standards, trying to be the best and avoiding judgments of low ability or appearing dumb (Pintrich, 2000; Pintrich & Schunk, 2002).

The most important aspect of goal theory is the distinction between mastery and performance goals and how these goals are linked to different cognitive, motivational and behavioral mediators and outcomes (Pintrich, 2000; Pintrich & Schunk, 2002). Generally, the research suggests that a mastery goal orientation leads to adaptive attributional patterns, positive affect and interest, higher levels of cognitive engagement, more effort and persistence and adaptive help-seeking and risk-taking. In contrast, an avoid performance goal orientation (avoiding looking dumb or stupid) often leads to maladaptive patterns of attribution, higher levels of anxiety, lower value for tasks, less cognitive engagement, withdrawal of effort and failure to persist and lower levels of performance (Pintrich & Schunk, 2002).

On the basis of this theoretical background, a number of researches propose some instructional strategies that teachers can use in their classrooms to develop their students' cognitive and metacognitive skills, to enhance their self-efficacy beliefs and make them more mastery oriented. Although all of these studies suggest guidance for supporting students' different aspects of self-regulated learning skills, most common suggestions are having students inquiry learning activities (Schraw, Crippen & Hartley, 2006; Kipnis & Hofstein, 2008) and encouraging self-recording and self-reflection techniques (Smith, 2001; Zion, Michalsky & Mevarech, 2005) such as inventory instruments and dairies in terms of metacognitive development; designing tasks in an appropriate level of challenging, permitting the students to express their opinion, giving positive feedbacks to students' assignments (Schunk, 1988; Schunk, 1991; Smith, 2001; Taylor & Corrigan, 2005) and encouraging them to see that errors are part of the learning process rather than evidence of ability (Smith, 2001; Taylor & Corrigan, 2005) in order to enhance self-efficacy; focusing on meaningful aspects of the task, providing opportunities for students to have some choice and control over the activities, de-emphasizing competition and social comparisons, encouraging peer interaction and recognizing student effort regarding mastery goal orientation in the classroom (Pintrich & Schunk, 2002; Smith, 2001). However, seldom of these researches emphasize both on metacognition and motivation.

2. Methodology

2.1. Purpose

The main goal of the research is to investigate the effect of the learning method aimed to develop students' metacognitive awareness embedded within a motivating chemistry lab on students' metacognitive skills. Relating to their metacognitive development, this study addresses two issues:

1. Is there any significant difference between students taught by the traditional method and the method, aimed to improve students' metacognitive skills embedded within a motivating lab, in terms of their science process skills?
2. Is there any significant difference between students taught by the traditional method and the method, aimed to improve students' metacognitive skills embedded within a motivating lab, in terms of their attitudes towards chemistry?

2.2. Sample

Fifty-four pre-service science teachers entering the General Chemistry Laboratory-I course at Marmara University Atatürk Education Faculty, Department of Primary Education, Science Education Program in the second semester of 2007-2008 participated in this study. The population was randomly assigned into two instructional treatment classes, one of which was control (n=27), and the other was experimental group (n=27). The students in the control group were taught traditionally, while the students in the experimental group were taught by an instructional method intending to develop students' metacognitive skills embedded within a motivating chemistry lab.

2.3. Procedure

In order to assess the impact of the instructional strategy carried in experimental group compared to a more standard lab experience, an experiment was designed so that control and experimental groups would be as similar as possible. To achieve this, a great effort was made to insure that primary difference between the two groups was learning environment provided in the laboratory, accompanying a general chemistry lecture class. First, the students in both control and experimental group carried out the same 11 experiments, each of which was performed over a lab course. The topics of the experiments were as follows:

- The effect of the type of the substance on reaction rate
- The effect of the concentration on reaction rate
- The effect of temperature on reaction rate
- Chemical equilibrium
- Precipitation and solubility product
- Weak and strong acids/bases, neutral substances and the concept of pH
- Indicators
- Weak acids/bases and ionization constant of acids/bases
- Buffer solutions
- Acid-base titration
- Hardness of water

Second, both of the groups were taught by the first author and these two groups were taught together by an experienced instructor (the second author) in accompanying general chemistry lecture. Third, both of the groups were taught in similar time periods (approximately 2 hours). Fourth, all of the students performed the experiments in small groups (three or four students in each group).

The students in the control group performed the experiments following the instructions described in the laboratory manual. Students were given the topic, aim and the procedure of the experiment. The researcher gave required information before and after performing of the experiments and answered the questions the students posed, but no additional effort was taken during the course in control group. However, in the experimental group pre- and post-discussions about the design of the experiments were held in order to create metacognitive awareness of the experimental design. Through these discussions it was aimed to make the students be aware of scientific knowledge and science process skills in regards of each experiment. The students in the experimental group were encouraged to design the experiments and interact to their peers and teacher. They were always provided with positive feedback (e.g., "You are doing well" or "I can see you are trying hard") during the experiment, while the students in the control group had not any such feedback. The students in the experimental group were also given four semi-structured reflective interview forms. The second and the third form reflected students' ideas about the experiment and the topic related to the experiment before and after the course. The first and the last interview forms, which were given at the beginning and the end of the semester, revealed students beliefs and expectations about the lab course and were used for a deeper analysis of the students' metacognitive skills, motivation and attitude towards the course.

All of the students were asked to write a report of the experiment and to answer the questions described in their laboratory manual. Differently from the control group, the students in experimental group were asked to inquire the subjects the researcher wanted them to do so. The students in experimental group were not only informed about the errors they made in their reports but also had always positive feedbacks, such as "Thank you for this elaborate and neat study" or "Well done!" If a report was not good enough the feedback given was a sentence something like "I believe that you can do much better if you try." The students in control group had no feedback for their reports.

The teaching method implemented in the experimental group depended on Pintrich's (2000) model of four phases of self-regulation: planning, monitoring, controlling and reflecting. The authors adapted Pintrich's learning model to the chemistry lab course and developed a teaching method, consisted of five phases: introduction, awareness and planning, performing the experiment, self-control and self-assessment and reflection.

1. *Preparatory:* The courses began with the second reflective form, which the teacher asked the students to fill and submit before the experiment. The questions in this form aimed to improve students' metacognitive skills by making them set their goals and be aware of their goal orientations and self-efficacy beliefs. After submitting these forms, the teacher posed one or several questions, those of which were intended for the design of the experiment or a problem encountered in daily life.
2. *Awareness and planning:* The question posed to the class in the first phase was elaborated in this phase. The students discussed this question first in small groups, then with other groups of the class. The teacher interfered in these discussions by asking appropriate questions to the students, but without directing them. The purpose of this phase was to enhance students' motivation, planning skills and understanding of scientific knowledge and scientific processes regarding the experiment and also to make them aware of the reason of doing this experiment.
3. *Performing the experiment:* Following the discussions, the students performed the experiment that they designed all together. The researcher (first author) watched them carefully and tried to give positive feedbacks and encourage the students asking questions as much as possible.
4. *Self-control:* The students tested their hypotheses by discussing the results of the experiment. In this phase the researcher made explanations if necessary.
5. *Self-assessment and reflection:* In this last phase, the researcher sometimes made a demonstration experiment, related to the experiment that has just been performed and asked questions about that demonstration experiment or sometimes wanted the students to inquire a problem. By this way it was aimed to make the students to assess themselves about their learning and improve their inquiry skills. The researcher asked the students to answer the questions in lab manual and the researcher posed them in their reports which would be delivered next week. The students were assigned to write reports, and the researcher added her feedback in the reports after reading them and returned them to the students. At the end of the course the students were asked to fill and submit the third reflective form. The questions in this form aimed to improve students' metacognitive skills by making them aware whether there was a change in the goals they set, their goal orientations and their self-efficacy beliefs.

2.4. Instruments

Science Process Skills Test (SPST): Turkish version of this test was used both as pre- and post-test to determine the students' science process skills. This test had been developed by Burns, Okey, & Wise (1985) and was adapted to Turkish by Özkan, Geban & A kar (1990). Five different science processes were measured on the SPST: (1) identifying variables, (2) identifying and stating hypotheses, (3) operationally defining, (4) designing investigations, and (5) graphing and interpreting data. The SPST is a 36 multiple choice item instrument that includes the five aforementioned dimensions. The Cronbach alpha reliability coefficient of the Turkish version of this instrument is 0.85.

Attitude Towards Chemistry Scale (ATCS): The ATCS, 12-item survey is based on a 5-point Likert scale. It was designed by Berbero lu (1993) to test five different student attitudes: (1) interest in chemistry, (2) attitudes towards laboratory, (3) attitudes towards chemistry as professional, and (4) anxiety towards chemistry. Students chose a number between 1 and 5 to show whether they agreed with the statement (5) or disagreed with the statement (1). The Cronbach alpha reliability coefficient of this instrument is 0.87. This scale was used both as pre- and post-test.

Motivated Strategies for Learning Questionnaire (MSLQ): The MSLQ is the 81-item self-report instrument designed by Pintrich, Smith, Garcia & Mc Keachie (1991) to test college students' motivational orientation and their use of different learning strategies for a college course and was adapted to Turkish by Altun (2005). There are two sections that make up the original instrument: a motivation section and learning strategies section. The motivational subscales are based on general social cognitive model of motivation that proposes three general constructs (Pintrich, 1988): expectancy, value and affect. Motivation section tests 6 different student perceptions: intrinsic and extrinsic goal orientation, task value, control of learning beliefs, self-efficacy beliefs and test anxiety. Participants responded all of the items in this scale and all of results of motivation section will be presented in this paper.

The learning strategies section is based on a general cognitive model of learning and information processing (Weinstein & Meyer, 1986). This has three general types of scales: cognitive, metacognitive and resource management. Metacognitive section of the scale the participants responded will be presented in this paper.

The items associated with categories of the MSLQ are scored on a 7-point Likert scale, from 1 (not very much like me) to 7 (very true of me). The validity and the reliability analysis of the Turkish version of the survey were made by Altun (2005). The Cronbach alpha reliability coefficients of the categories in motivation section are 0.80 for intrinsic goal orientation; 0.83 for extrinsic goal orientation; 0.91 for task value; 0.80 for control of learning beliefs; 0.89 for self-efficacy beliefs; and 0.82 for test anxiety. The Cronbach alpha reliability coefficient of metacognitive learning strategies is 0.85 (Altun, 2005; Altun & Erden, 2006). This survey was used as both pre- and post-test.

3. Results and Discussion

The data obtained from the study were assessed by using SPSS program. Prior to treatment, an independent t-test was employed to determine whether a statistically significant difference between control and experimental groups with respect to science process skills, attitude towards chemistry and motivational beliefs and use of different learning strategies. The hypotheses were tested in the 0.95 confidence interval. The results of independent samples t-test analysis showed that there were no significant differences between the control and the experimental group in terms of their science process skills (SPST) ($t=1.334$; $df=52$; $p>0.05$), attitude towards chemistry (ATCS) ($t=0.598$; $df=52$; $p>0.05$) and MSLQ scores ($t=1.180$; $df=52$; $p>0.05$). There was no significant difference between two groups in terms of their pre-test scores of subscales of three tests either. This result indicated that students in experimental and control groups were similar regarding these three variables.

After the treatment, SPST, ATCS and MSLQ were utilized as post-tests to both control and experimental groups. The t-test analysis indicated that students in experimental group outperformed students in control group in the post-test scores of SPST (Table-1). Because the process skills tested represented the rational and logical thinking skills that have great influence in students' understanding of science (Sungur, Tekkaya & Geban, 2001), this result is important for our research. When the subscales of SPST were analyzed it could be seen that the students in the experimental group were more successful than the students in the control group in the subscales of identifying variables, operationally defining, and designing investigations (Table-2).

Table-1 Post-Test Results of SPST

	Group	N	Mean	SD	df	t	p
SPST	control	27	24.19	4.707	52	2.317	0.02*
	experimental	27	26.79	3.412			

*p<0.05

Table-2 Post-Test Results of Subscales of SPST

	Group	N	Mean	SD	df	t	p
Identifying variables	control	27	6.48	2.064	52	2.055	0.04*
	experimental	27	7.70	2.301			
Identifying and stating hypotheses	control	27	6.67	1.710	52	0.483	0.63
	experimental	27	6.85	1.027			
Operationally defining	control	27	4.00	1.240	52	2.501	0.01*
	experimental	27	4.89	1.368			
Designing investigations	control	27	2.04	0.808	52	2.221	0.03*
	experimental	27	2.44	0.506			
Graphing and interpreting data	control	27	5.00	0.920	52	0.462	0.64
	experimental	27	4.89	0.847			

*p<0.05

No significant differences were found between two groups either in the total scores of ATCS ($t=1.189$; $df=52$; $p>0.05$) or those of the four of ATCS: attitudes towards laboratory ($t=0.692$; $df=52$; $p>0.05$), attitudes towards chemistry as professional ($t=1.095$; $df=52$; $p>0.05$), interest in chemistry ($t=0.968$; $df=52$; $p>0.05$), and anxiety towards chemistry ($t=1.353$; $df=52$; $p>0.05$). However, the students stated that this course contributed to their learning and had pleasure of performing experiments in the reflective forms. On the other hand, they frequently complained about filling these reflective forms.

The results of independent t-test analysis of the post-test scores of MSLQ showed that the teaching method did not affect the students' motivational beliefs in total (Table-3) but the scores of the subscales of control of learning beliefs and self-efficacy beliefs of the students in the experimental group were significantly higher than those of the students in the control group (Table-4). Providing positive feedback on students' abilities may enhance self-efficacy, skill performance and ultimately motivation. Attributing a learning outcome to something that is controllable is also fundamental to enhance motivation (Smith, 2001). The designed approach in this study seem to achieved the goals of providing positive feedbacks and attributing a learning outcome to something that is controllable with respect to self-efficacy and control of learning beliefs.

Table-3 Post-Test Results of Motivation Section of MSLQ

	Group	N	Mean	SD	df	t	p
Motivational Beliefs	control	27	149,74	31,506	52	1,358	0,180
	experimental	27	159,07	16,808			

*p<0.05

Table-4 Post-Test Results of Subscales of Motivation Section

	Group	N	Mean	SD	df	t	p
Intrinsic goal orientation	control	27	20.93	5.993	52	0.637	0.53
	experimental	27	21.85	4.605			
Extrinsic goal orientation	control	27	20.11	5.466	52	1.590	0.12
	experimental	27	22.15	3.800			
Task value	control	27	31.00	7.651	52	0.058	0.95
	experimental	27	30.89	6.399			
Control of learning beliefs	control	27	21.48	4.957	52	2.102	0.04*
	experimental	27	23.70	2.367			
Self-efficacy	control	27	38.52	9.717	52	2.051	0.04*
	experimental	27	43.00	5.870			
Test anxiety	control	27	17.70	5.980	52	0.142	0.88
	experimental	27	17.48	5.501			

*p<0.05

The post-test scores of metacognitive learning strategies subscale of MSLQ showed that the students in the experimental group used more metacognitive learning strategies than did the students in the control group (Table-5). Self-recording is one of the most common methods of increasing student awareness of learning behaviors and enabling students to students to evaluate progress toward a goal. Self-recording includes various forms of reflective writing that requires students to put into writing their thoughts, ideas, and questions with respect to a certain topic. Use of inventory instruments can also add value to a student's self-awareness by forcing him/her to consider specifically what he or she was thinking about before, during, and after the learning process (Smith, 2001). In addition to the reflective forms, which seem to have increased students' self-awareness, according to Kipnis and Hofstein (2007), the inquiry laboratory provides the students with the opportunity for metacognitive activities.

Table-5 Post-Test Results of Metacognitive Strategies

	Group	N	Mean	SD	df	t	p
Metacognitive learning strategies	control	27	58.00	11.520	52	2.282	0.03*
	experimental	27	64.44	9.095			

*p<0.05

4. Conclusion

The main purpose of the present study was to improve science process skills and attitudes towards chemistry through the development of metacognitive skills embedded within a chemistry laboratory. Through a review of related research studies, support is clear that science process skills can be taught and learned if the students have an appropriate amount of experience exposed to the situation dealing with this ability (Mattheis & Nakayama, 1988). Besides, the results of this study show that developing student' metacognitive awareness within a motivating laboratory improved their skills of identifying variables, designing investigations, and their operational skills more than a traditional laboratory.

Although the students in the experimental group defined the experiments they performed as instructive and enjoyable in reflective forms the difference in neither of four attitudes towards chemistry was found significant between the groups. It seems that more time is needed to achieve any gain in a standardized instrument such as attitude survey. Another possible reason may be that the students' unwillingness of filling the reflective forms has affected their attitude towards the course negatively.

The approach used in this study also enhanced students' self-efficacy beliefs. This learning environment also seems to help students' control of learning beliefs. In other words, students tend to believe that their success or failure depends on their efforts for the task. This kind of laboratory course also encourages students to share their ideas with peers, help them cognitively, metacognitively and motivationally engage in learning process and by this way make them have pleasure the laboratory.

The findings of this study support the findings of previous studies showing the positive effects of metacognitive guidance on learning outcomes (Tien, 1998; Zion, Michalsky, & Mevarech, 2005). Because students in experimental group designed the experiments, discussed every step of the experiments with their peers, inquired some problems related to the topic of the experiment, and get feedback from the researcher, it is not surprising that students developed their skills of identifying variables, operationally defining, and designing investigations included in science processes. The students in both control and experimental group seem to achieve the skills of identifying and stating hypotheses, and graphing and interpreting data. This phenomenon could be explained that laboratory procedure and writing reports for experiments allow students to improve their mentioned skills without the need of any additional effort.

In spite of the development of metacognitive skills, no significant differences were found in students' test scores of motivational beliefs in total. However, students' control of learning beliefs and self-efficacy beliefs seem to have improved over the course period. This result indicated that the teaching method carried in experimental group enhanced students' expectancy beliefs, rather than their value beliefs and affective states. One possible reason of not achieving any gain in students' value beliefs and affective states could be explained by short instruction period (11 weeks). Another possible reason may be the lack of clear goals that emphasize learning over grades, which will increase intrinsic motivation (Young, 2005).

Green (2002) has suggested that task value will be promoted whenever the teacher provides a reason for the task, emphasizes the usefulness and importance of the task, emphasizes the enjoyment that can be gained from the task, offers choice within the task, and models enthusiasm for the task. In order to improve students' metacognitive skills and make them use more diverse metacognitive skills, students were asked the usefulness and importance of the course and whether they enjoyed the experiments they performed in the reflective forms given at the end of the course. In these reflective forms, the students expressed various reasons for the usefulness and importance of the course and that they had pleasure with performing the experiments in these reflective forms. They also stated that the feedbacks the teacher gave to their reports have contributed to their learning and motivated them. However, the teacher emphasize on these issues was lacked in this study.

Overcoming the potential limitations of this study provides guidance for further research. First, this study was based on a sample from one university, suggesting that replication in alternative educational settings is needed for greater generalization. Studies in other science laboratories, with secondary and high school students are needed.

Second, longer instructional periods may be needed for accomplishing the development of learning strategies and motivational beliefs. Longitudinal studies may be essential in this respect.

Third, this study focuses on guided inquiry, in which students are required to identify the scientific problem, analyze data, formulate hypotheses, design experiments to test the hypotheses, and explain the chemical phenomenon for the basis of the experiments. However, an open inquiry activity, which requires students to design a follow-up experiment based on both the information cited in the previous experiment and on new information (Zion, Michalsky & Mevarech, 2005) they will search as homework, may be included in such a study. As Zion, et al. (2004) suggested, emphasizing the dynamic characteristics of the open inquiry process may assist in the judgment and justification processes. Since argumentation would predict success at problem-solving processes (Cho & Jonassen, 2002; Hong et al, 2001), we also suggest adding to lab courses argumentation process that allow students to defend their solutions.

References

Altun, S. (2005). Ö rencilerin Öz Düzenlemeye Dayalı Ö renme Stratejilerinin ve Öz Yeterlik Algılarının Ö renme Stilleri ve Cinsiyete Göre Matematik Ba arısını Yordama Gücü. *Dissertation of Ph.D. submitted to the Graduate Faculty of Yıldız Teknik University*: stanbul.

Altun, S., & Erden M. (2006). Ö renmede Motive Edici Stratejiler Ölçe inin Geçerlik ve Güvenirlik Çalı ması. *EDU 7, 2*(1), 16.

Ames, C. (1992). Classrooms: Goals, structures, and student motivation. *Journal of Educational Psychology. 84*, 261-271.

Appleton, K. (2002). Science activities that work: Perceptions of primary school teachers. *Research in Science Education. 32,* 393-410.

Bandura, A. (1977). *Social Learning Theory.* 161-165. NJ. Prantice-Hall.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory.* Englewood Cliffs, NJ. Prantice-Hall.

Baird, J.R. (1986). Improving learning through enhanced meacognition: A classroom study. *European Journal of Science Education. 8*, 263-282.

Berbero lu, G. (1993). Kimyaya Yönelik Tutumlara li kin Çok Boyutlu Bir Ölçe in Geli tirilmesi. *E itim ve Bilim. 17*(87), 29-36.

Burns, J.C., Okey, J.R., & Wise, K.C. (1985). Development of an integrated process skill test: TIPS II. *Journal of Research in Science Teaching. 22*(2), 169-177.

Cho, K., & Jonassen, D.H. (2002). The effect of argumentation scaffolds on argumentation and problem solving. *Educational Technology Research and Development. 50*, 5-22.

Davidowitz, B. & Rollnick, M. (2003). Enabling metacognition in the laboratory: A case study of four second year university chemistry students. *Research in Science Education. 33*, 43-69.

Dweck, C.S. & Leggett. E.L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review. 95*, 256-273.

Eccles, J. (1983). Expectancies, values and academic behaviors. In J. T. Spence (Ed.), *Achievement and achievement motives* (pp.75-146). San Francisco: Freeman.

Eccles, J., Wigfield A., Flanagan, C., Miller, C., Reuman, D. & Yee, D. (1989). Self-concepts, domain values, and self-esteem: Relations and chancecs at early adolescence. *Journal of Personality. 57*, 283-310.

Freedman, M. P. (1997). Relationship among laboratory instruction, attitude toward science and achievement in science knowledge. *Journal of Research in Science Teaching. 34*(4), 343-357.

Garcia, C. (2004). The Effect of Teacher Attitude Experience and Background Knowledge on the Use of Inqury Method Teaching in the Elementary Classroom. *The Texas Science Teacher.* 24-31.

Garnett, P.J., Garnett, P.J. & Hacking, M.W. (1995). Refocusing the chemistry lab: A case for laboratory-based investigations. *Australian Science Teachers Journal. 41*, 26-32.

Geban, Ö. (1990). Effects of Two Different Instructional Treatments on the Students' Chemistry Achievement, Science Process Skills, and Attitudes Towards Chemistry at the High School Level. *Dissertation of Ph.D. submitted to the Graduate Faculty of Middle East Technical University*: Ankara

Georghiades, P. (2004). From the general to the situated: Three decades of metacognition. *International Journal of Science Education. 26*, 81-96.

Gourgey, A.F. (1998). Metacognition in basic skills instruction. *Instructional Science. 26*, 81-96.

Green, S.K. (2002). Using an expectancy-value approach to examine teachers' motivational strategies. *Teaching and Teacher Education. 18*, 989-1005.

Hart, C., Mulhall, P., Berry, A. & Gunstone, R. (2000). What is the purpose of this experiment? Or can stdents learn something from doing experiments? *Journal of Research in Science Teaching. 37,* 655-675.

Hofstein, A. & Lunetta, V.N. (1982). The role of the laboratory in science teaching : Neglected aspects of research. *Review of Educational Research. 52*, 201-217.

Hofstein, A. & Lunetta, V.N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education. 88*, 28-54.

Hodson, D. (1996). Practical work in school science: exploring some directions for change. *International Journal of Science Education. 18*, 755-760.

Hong, N.S., McGee, S., Howard, B.C. (2001). Essential components for solving various problems in multimedia learning environments. *Paper presented at the Annual Meeting of the American Educational Research Association.* Seattle, WA.

Kipnis, M. & Hofstein, A. (2008). The inquiry laboratory as a source for development of metacognitive skills. *International Journal of Science and Mathematics Education. 6*, 601-627.

Locke, E.A. & Latham, G.P. (1990). *A theory of goal setting and task performance.* Englewood Cliffs, NJ: Prantice-Hall.

Maehr, M.L. & Midgley, C. (1991). Enhancing student motivation: A schoolwide approach. *Educational Psychologist. 26*, 399-427.

Mattheis, F.E., & Nakayama, G. (1988). Effects of a laboratory-centered inquiry program on laboratory skils, science process skills, and understanding of science knowledge in middle grades students. *Reports-Research.* Pp.26.

Mulholland, J. & Wallace, J. (1999). Learning and Teaching Elementary Science in the Transition from Preservice to Inservice Teaching. *Paper presented at the Annual Meeting of the American Educational Research Association* (Montreal, Quebec, Canada, April 19-23, 1999).

Nicholls, J. (1984). Achievement motivation: Conceptions of ability, subjective experience, task choice, and performance. *Psychological Review. 91*, 328-346.

Pintrich, P.R. (1988). Student learning and college teaching. In R. E. Young & K. E. Eble (Eds.). *College Teaching and Learning: Preparing new commitments. New directions for teaching and learning* (pp.71-86). San Francisco: Jossey-Bass.

Pintrich, P.R. (2000). The roal of goal orientation in self-regulated learning. In M. Boekaerts, P. R. Pintrich & M. Zeidner (Eds.), *Handbook of Self-Regulation: Theory, Research and Applications.* 452-502. San Diego, CA: Academic.

Pintrich, P.R., & Schunk, D.H. (2002). *Motivation in Education: Theory, Research and Applications.* Englewood Cliffs, NJ: Prentice Hall Merrill.

Rickey, D. & Stacey, A.M. (2000). The role of metacognition in learning chemistry. *Journal of Chemical Education. 77*, 915-920.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Sciences. 26*, 113-125.

Schraw, G., Crippen, K.J. & Hartley, K. (2006). Promoting Self-Regulation in Science Education: Metacognition as Part of a Broader Perspective on Learning. *Research in Science Education. 36,* 111-139.

Schunk, D.H. (1988). Perceived self-efficacy and related social cognitive processes as predictors of student academic performance. *Paper presented at the Annual Meeting of the American Educational Research Association* (New Orleans, LA, April 5-9, 1988).

Schunk, D.H. (1991). Self-efficacy and academic motivation. *Educational Psychologist. 26*(3 & 4), 207-231.

Shimizu, T. (1997). Teachers' emphasis on inquiry science and prevailing instructional method. *Paper presented at the Annual Meeting of the Naitonal Association for Research in Science Teaching*. pp. 23.

Shuh, T.G. (2002). An introduction to lipid analysis in the cell biology laboratory. *The American Biology Teacher. 64,* 122-129.

Smith, P. (2001). Understanding self-regulated learning and its implications for accounting educators and researchers. *Issues in Accounting Education. 16*(4), 1-38.

Stuart, M.D. & Henry, R.W. (2002). Plastinated specimens can improve conceptual quality of Biology labs. *The American Biology Teacher. 64,* 130-134.

Sungur, S., Tekkaya, C., & Geban, O. (2001). The contribution of conceptual change texts accompanied by mapping to students' understanding of the human circulatory system. *School Science and Mathematics. 101*(2), 91-101.

Talsma, V.L. (1996). Science Autobiographies: What do they tell us pre service elementary teachers' attitudes towards science and science teaching. *Paper Presented at the Annual Meeting of the National Association for Research in Science Teaching* (Sti Louis, MO, April 2, 1996).

Tarık, T. (2000). The beliefs of pre service elementary teachers towards science and science teaching. *School Science & Mathematics. 100*, 376-381.

Taylor, N. & Corrigan G. (2005). Empowerment and confidence: Pre-service teachers learning to teach science through a program of self-regulated learning. *Canadian Journal of Science. 5*(1), 41-61.

Thomas, G.P. & McRobbie, C.J. (2001). Using a methaphor for learning to improve students metacognition in the chemistry classroom. *Journal of Research in Science Teaching. 38*, 222-259.

Tien, L.T. (1998) fostering expert inquiry skills and beliefs about chemistry through the MORE laboratory experience. *Dissertation of Ph.D. submitted to Science end Mathematics Education in the Graduate Division of the University of California, Berkeley.*

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics. 90*, 403-418.

Tsai, C-C. (2003). Taiwanese science students' and teachers' perceptions of the laboratory learning environments: exploring epistemological gaps. *International Journal of Science Education. 25*(7), 847-860.

Weinburgh, M.H. & Englehard, G.Jr. (1994). Gender, prior academic performance and beliefs as predictors of attitudes towards biology laboratory experiences. *School Science & Mathematics. 94*(3), 118-123.

Weinstein, C. & Meyer, R. (1986). The teaching of learning strategies. In M. Wittrock (Ed.). *Handbook of Research on Teaching.* (pp.315-327). New York: MacMillan.

Wigfield, A. (1994). Expectancy-value theory of achievement motivation: A developmental perspective. *Educational Psychology Rewiev. 6*, 49-78.

Wigfield, A. & Eccles, J. (1992). The development of achievement task values: A theoretical analysis. *Developmental Rewiev. 12*, 265-310.

Wigfield, A. & Eccles, J. (2000). Expectancy-value theory of achievement motivation. *Contemporary Educational Psychology. 25*, 68-81.

White, R.T. & Mitchell, I.J. (1994). Metacognition and quality of learning. *Studies in Science Education. 23*, 21-37.

Young, M.R. (2005). The Motivational Effects of the Classroom Environment in Facilitating Self-Regulated Learning. *Journal of Marketing Education. 27*(25), 25-40.

Zimmerman, B.J. (1986). Becoming a self-regulated learner: Which are the key subprocesses. *Contemporary Educational Psychology. 11*, 307-313.

Zion, M., Michalsky, T. & Mevarech, Z.R. (2005). The effects of metacognitive instruction embedded within an asynchronous learning network on scientific inquiry skills. *International Journal of Science Education. 27*(8), 957-983.

Zion, M., Slezak, M., Shapira, D., Link, E., Bashan, N., Brumer, M., Orian, T., Nussinowitz, R., Court, D., Agrest, B., Mendelovici, R., & Valanides, N. (2004). Dynamic, open inquiry in biology learning. *Science Education. 88*, 728-753.